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## ***Perspectives on How Academia is Keeping Pace with the Changing Needs of Manufacturing Professionals***

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# Perspectives on How Academia is Keeping Pace with the Changing Needs of Manufacturing Professionals

By Dr. Martin P. Jones, Mr. Rathel R. Smith & Dr. R. Neal Callahan

## Abstract

The present paper surveys the alignment of curriculum with the educational needs of manufacturing professionals and organizations. An analysis is presented of data from multiple surveys, regarding the skills needed by manufacturing professionals to meet the rapidly changing and increasingly competitive requirements of the manufacturing industry. One survey was separately administered to manufacturing professionals and manufacturing educators. It was found that there were several skill topics which both educators and professionals were in agreement regarding their importance in sustaining the productivity of manufacturing professionals. Among these agreed-upon skills are Lean Processes, Six Sigma, and CAD/CAM. As a follow-up to the above skill topics survey, a catalog survey of available university courses was performed to find courses that would enhance the agreed-upon needed skills for manufacturing professionals. The data from the catalog survey indicated gaps in course offerings in those agreed-upon skill topics. Furthermore, a phone survey of university department heads of The Association of Technology, Management, and Applied Engineering (ATMAE) accredited schools of technology supported the presence of the gap between skills needed and course offerings. A gap analysis was performed using the catalog and phone surveys. Recommendations are given to enhance inclusion and visibility of these agreed-upon skills in engineering and technology curricula.

## Introduction

Educational programs in Manufacturing Technology are increasingly under pressure due to a rapidly changing manufacturing environment and globalization. As globalization continues to accelerate, companies increasingly feel the pressure to become more productive and efficient. Manufacturing companies remaining in the United States face strong global competition as they strive to survive and grow (Lucena, 2006). Based on a survey of manufacturing professionals, recommendations are given to improve manufacturing curricula in response to global competition (Callahan, Jones, & Smith, 2008).

According to U.S. government data, the manufacturing sector accounts for about 20% of the gross domestic product (Bureau of Economic Analysis [BEA], 2009). This is somewhat lower than the 22-25% it has ranged for the past 50 years (Shinn, 2004). The remaining manufacturing professionals play an increasingly important role in improving the efficiency and competitiveness of the company. Manufacturing professionals in the U. S. are increasingly asked to perform new and different tasks. It is no longer acceptable to only understand the technical components of the operation. A broader understanding of the overall business environment, competitive forces, and trends is necessary to properly apply technical knowledge (Sinn, 2004).

## Background

Various continuous improvement tools are widely used in industry today as

a means for meeting these additional expectations placed on manufacturing professionals. Lean processes and Six Sigma methodologies are prominent examples of these tools which focus on elimination of waste, improvement of quality, and reduction of production lead time. Implementing related programs can improve value for the customer while increasing profits for the company (Summers, 2007). According to one recent survey conducted by Industry Week and the Manufacturing Performance Institute, 40% of manufacturers have implemented some form of Lean manufacturing program. Another 12% have implemented a combination of Lean and Six Sigma (Katz, 2007). Some companies considering outsourcing have found that they can stay competitive and meet financial goals by implementing Lean concepts while remaining in the United States. Small-to-mid sized companies in particular may be better off implementing Lean concepts rather than migrating offshore (Langer, 2007). There is critical need for universities to develop Lean manufacturing curricula (Fliedner & Mathieson, 2009; Williamson, 2006).

Six Sigma is frequently used in industry and university graduates are encouraged to be prepared (Goffnett, 2004). Rao and Rao (2007) suggest Six Sigma be offered as a full academic course. In a comprehensive survey of ATMAE's industry division members and academic leaders, DeRuntz and Meier (2004) find the top two topics of interest were Lean and Six Sigma. However, Meier and Brown (2008) point out that 45% of ATMAE accredited programs "... do not offer a Quality class."

Rapidly changing technology is also a factor in educating the manufacturing professional. Microtechnologies and nanotechnologies typify the trend toward converging technologies where several disciplines are critical in the development and manufacture of a product (Kalpakjian & Schmid, 2006). These new and developing industries require the same process improvement and efficiency skills as traditional manufacturing organizations. Examples

of products currently being developed around this convergence of disciplines include microsensors for healthcare testing, automation applications using intelligent software, and high performance materials using carbon nanotubes (McCann, 2006). These new industries and their associated technologies bring expectations and challenges to skilled professionals that must be addressed by the academic community in both continuing education and traditional college degrees.

Plaza (2004) proposed developing some core college technology courses around a topic involving several disciplines and instructors. This integrative approach could be particularly helpful at the introductory or capstone level course in demonstrating the importance and application of the convergence of technology. Related to integrated manufacturing is flexible manufacturing. A survey of more than 3,000 U. S. manufacturing organizations identifies the need for flexible manufacturing (Gale, Wojan, & Olmsted, 2002). Workers should have a "broader set of skills" which are needed in this manufacturing approach.

Advances in software and internet applications can play an important role in the success of a manufacturing organization. Software to support Lean and Six Sigma concepts is available in affordable packages. Internet-enabled software is now available in specialized segments allowing companies implement a Lean or continuous improvement program (Peake, 2003).

### **Purpose and Rationale**

This study continues the exploration of skills needed by manufacturing professionals to meet the requirements of the increasing competitive and technology driven manufacturing industry. The researchers developed a methodology to identify important skills and technologies required in the professionals' jobs and to recommend curricular change to enhance them. This paper is predicated on the results of a Society of Manufacturing Engineers (SME) industry survey originally relating to career opportunities and needed skills

for manufacturing professionals (Callahan, Smith, & Jones, 2007). A more recent survey of academia reveals agreement with manufacturing professionals concerning the most vital skills needed by the manufacturing professional. Among these agreed-upon skills are Lean Processes, Six Sigma, and CAD/CAM (Jones, Smith, & Callahan 2008). The present study involves two main questions:

1. How much do educators and professionals agree on what skills manufacturing professionals need to be successful in industry?
2. For curricula related to the agreed-upon skills, is there is a gap between what educators perceive as being offered and what is actually being offered through course catalogs?

The above two questions are tested as separate hypotheses. Regarding the first question, the researchers expected that educators and professionals would strongly agree on the skills needed by manufacturing professionals. It was reasoned that educators would be aware of current technologies and practices used in industry even though they might not be directly involved. Regarding the second question, it was also expected that there would be a curricular gap between what educators perceived as being offered and what actually is offered. It was reasoned that educators would be able connect concepts taught in their courses to current topics like Lean and Six Sigma but those connections would not be clearly identifiable in course catalog descriptions.

Furthermore, this paper makes additional recommendations to those previously given to enhance inclusion and visibility of these skills and topics in curricula (Callahan, Jones, & Smith, 2008). Additionally, the results of catalog course descriptions and a telephone survey of department heads of ATMAE accredited schools of technology regarding their course coverage of the critical needs of the manufacturing professional are presented. In a globally competitive environment, it is critical that schools of manufacturing technology and engineering provide relevant

curricula that address these skills. Recommendations are given regarding how academia can keep pace with the rapidly changing needs of manufacturing.

**Methodology**

**Research Methods**

The research method, depicted in Figure 1, was descriptive and correlational for this study. Three surveys and one review were used to obtain data. The Spearman Rank Correlation Coefficient,  $r_s$ , was used to infer the amount of agreement between educators and professionals in their responses to the survey questions. Descriptive statistics were used in the gap analysis to infer the average amount of curricular integration of the agreed-upon skills at ATMAE accredited schools, as estimated by department heads and through a survey of course catalogs.

**Participants**

Participants in the SME survey are referred to as “professionals” since 96.5% identified themselves as part of specific industries while only 0.4% were identified as academics (3.1% listed as “other”). Participants in the ATMAE survey are referred to as “educators” since 95% listed their position ranging from graduate student through the professor rank (5% listed as “other”). About 85% of the educators’ schools could confer four-year whereas 15% could confer two-year degrees. Figure 2 illustrates the percentage of educators with 4-year or advanced degrees is similar to that of professionals. In contrast, over twice the percentage of professionals were identified as having a 2-year degree as compared to educators. The percentages of participants with advanced degrees were about 30% for both educators and professionals.

**Procedure**

The SME survey method has been reported in detail (Callahan, Jones, & Smith, 2008). In brief, the survey was e-mailed during 2004 to approximately 5200 individuals, with 261 responding for a response rate of about 5%. Although a 5% response rate has traditionally been considered low, there are additional factors to consider that do

Figure 1. Overview of research method.

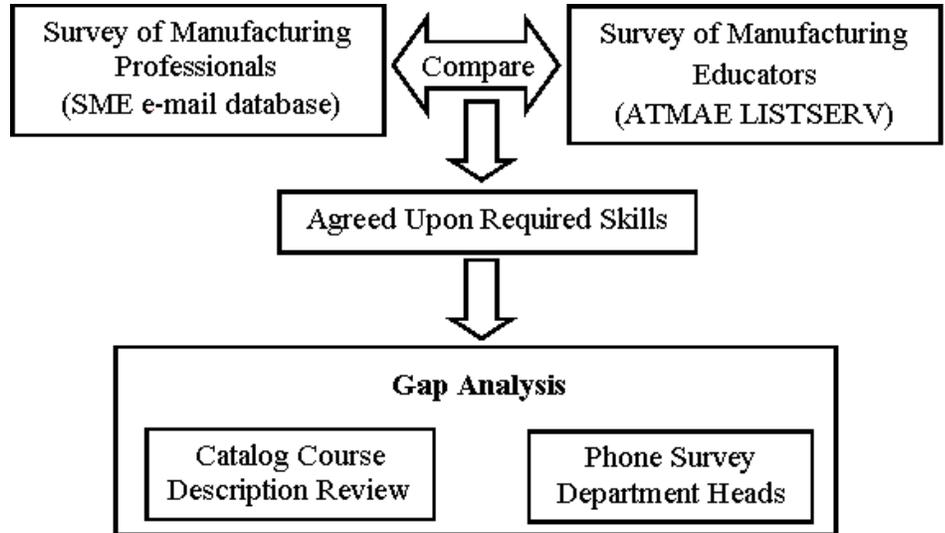
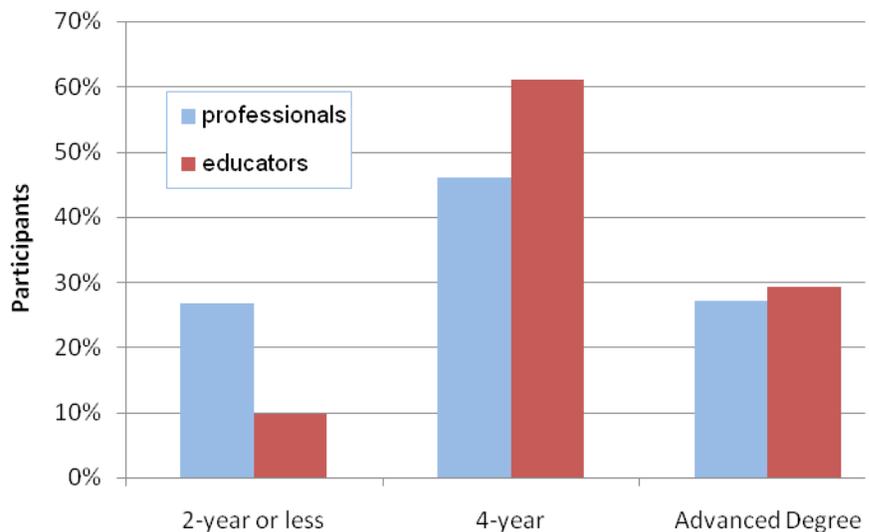


Figure 2. Education levels of SME/professionals and ATMAE/educators survey participants



support validity (Tanner, 1999; Wiseman, 2003).

A second survey similar in content to the SME survey was administered to educators in schools of technology associated with the ATMAE. The survey was e-mailed during 2007 to the approximately 200 manufacturing ATMAE LISTSERV subscribers with 41 responding. This response rate of 20% is representative of the manufacturing educators within ATMAE. The data were compared to the original SME data through Spearman rank order analysis to estimate the amount of

agreement of educators’ responses with that of professionals regarding skills needed by professionals. Professionals were in agreement with educators regarding needed skills. In reference to these agreed upon skills, a gap analysis was initiated to differentiate between what educators perceive as being offered and what is actually being offered by academia.

Two methods during 2008 were utilized for the gap analysis. First, a review of catalog course offerings descriptions was conducted utilizing university websites to determine coverage of

these topics in curricula. The university websites were selected from the ATMAE directory of schools having a manufacturing emphasis. Key terms (topics) searched in course titles and descriptions were Lean manufacturing, CAD/CAM, flexible manufacturing, integrated manufacturing, Six, Sigma, sensors technology, automated material handling. These topics were chosen since both the SME and ATMAE survey participants ranked them as the skills/technologies most needed by manufacturing professionals. When the topic was in the course title or predominant in the description, the number of credit hours was recorded as “dedicated.” This effort revealed 60 of the 84 ATMAE accredited schools with adequate information on their website to be included in the data.

Second, a telephone survey of department heads seeking their view of the coverage of these topics in curricula was conducted from the selected 60 ATMAE accredited schools. Researchers attempted to contact by phone the department heads of all 60 schools. Of these, 29 department heads were contacted and all participated in the survey. They were asked only to estimate how many courses and credit hours were dedicated to each of those topics at their school. Their estimates were recorded after the caller read each topic.

## Results

### Survey of Educators and Professionals

One basic measure of the educational needs is the level of education attained. To address this, both the professional and educator groups were asked the following question: “In your opinion, what is the minimal required level of formal training needed by a manufacturing engineer or technologist?” Figure 3 shows the response to this question from both groups.

The professional group, which consisted of a higher percentage of “2-year or less degrees,” had a higher response for that degree level as the minimal education than did the educator group. Similarly, the educator group, which

Figure 3. Participant opinion response on minimal education level needed.

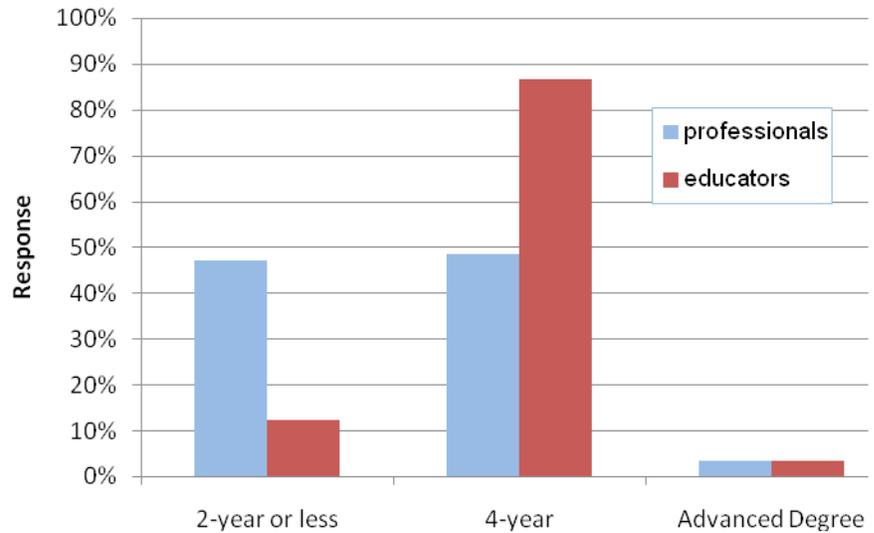


Table 1. Choices for Areas of Continuing Education or Training for Manufacturing Professionals

- A. Lean Manufacturing
- B. Quality Management
- C. Six-Sigma
- D. CAD or Modeling
- E. Statistical Analysis
- F. Facilitator/Train the Trainer
- G. Leadership or Supervisory
- H. New Processes and Technologies
- I. New Materials
- J. None of the above

consisted of a higher percentage of “4-year degrees,” had a higher response for that level as the minimal education than did the professional group. Therefore, Figure 3 indicates a clear difference of opinion between professionals and educators regarding the minimum education needed by manufacturing professionals.

Focusing on specific skills, participants were asked “What areas of continuing education or training are important to the manufacturing professional in today’s environment? Mark all that apply.” The choices of areas were as listed Table 1 above.

The responses to the above “continuing education” question are depicted in Figure 4. Note the professional participants’ responses are arranged from highest to lowest percentage response. The corresponding responses

from the educator participants are listed alongside the professionals’. Participants were also asked the same question regarding continuing education but with respect to the future: “What areas of continuing education or training are important to the manufacturing professional over the next 10 years? Mark all that apply.” The choices of areas were the same as listed in Table 1 and the responses are depicted in Figure 5.

Another basic measure of educational needs is the areas of responsibilities required of a manufacturing professional in the workplace. An assumption is that rapidly changing areas of responsibilities may necessitate development of new educational curricula to provide initial or continuing education relevant to manufacturing practice. To address this, both professionals and educators were asked the following question: “In your opinion, choose the most impor-

tant areas where a manufacturing engineer or technologist would be regularly involved and responsible. Mark all that apply.” Table 2 gives the choices from which the participants could select:

Figure 6 shows the responses of the professionals compared to the responses of the educators for the same choices. The highest three response rankings were the same for both the educator and professional participants. The highest five response rankings were the same for both groups except the educator participants identified “D. Selecting or ...” as 4<sup>th</sup> with respect to response percentages. Professional participants identified “M. Researching new...” as 4<sup>th</sup> with respect to response percentages, but the educator group did not list this choice in the top ten.

New technologies, whether they are based on equipment or management approaches, are needed to keep manufacturers competitive now and in the future. Participants were also asked to consider the following list of technologies with respect to their present importance through the following question and choices: “In your opinion, what technologies are manufacturing engineers or technologists required to use in today’s environment? Mark all that apply.”

Participants were also asked to consider the same technologies listed in Table 3 with respect to their future importance through the following question: “In your opinion, of the technologies listed

Figure 4. Response on present important areas of continuing education.

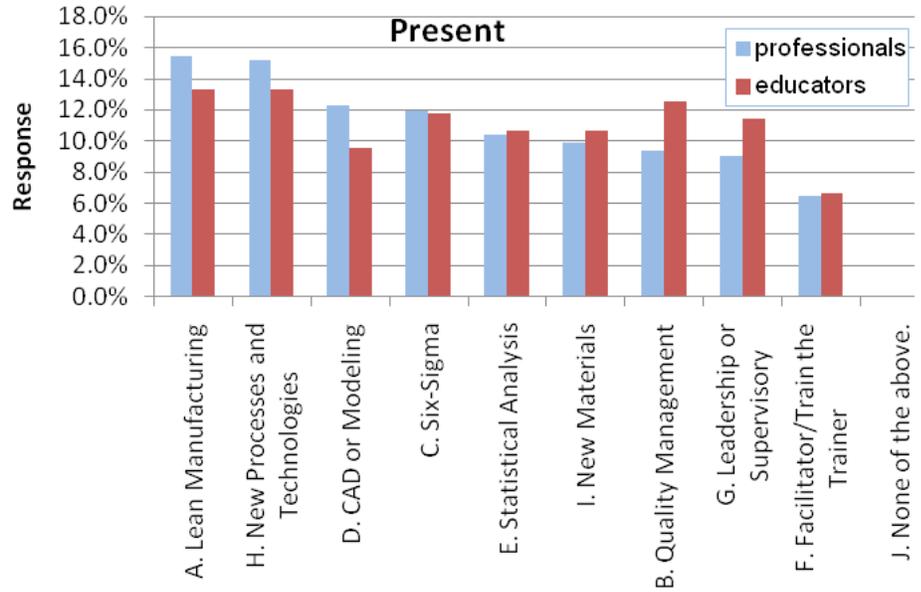


Figure 5. Response on future important areas of continuing education.

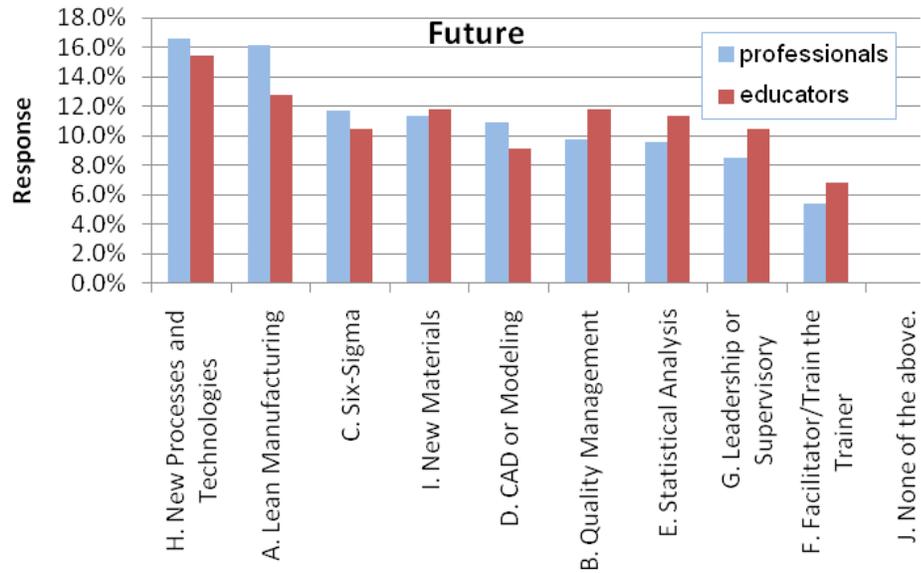


Table 2. Choices of Most Important Areas for Manufacturing Professionals to be Involved

A. Designing new products and product features	J. Interfacing directly with customers
B. Developing manufacturing methods, processes and systems	K. Supervising production operations
C. Troubleshooting production problems	L. Preparing capital spending plans and business-case justifications.
D. Selecting or designing equipment and tooling for manufacturing	M. Researching new methods/processes for improving future manufacturing
E. Supervise professional staff	N. Interfacing with vendors/purchasing
F. Facilitating process improvement methodologies on the factory floor (Lean, etc.)	O. Education and training
G. Factory floor layout and design	P. Quality assurance/quality control
H. Financial analysis	Q. Production scheduling/inventory control
I. N/C; CNC machine programming	R. Maintaining equipment and facilities
	S. Other

above, which do you see increasing in importance over the next ten years for manufacturing engineers or technologists? Mark all that apply.” Figures 7 and 8 depict the participants responses to the above last two questions.

To test for significance of these correlations, at an alpha level 0.05, the following hypothesis was tested:

$$H_o: p_s = 0 \text{ (reject } H_o \text{ if } p_s \leq .05)$$

$$H_a: p_s \neq 0$$

Under the null hypothesis ( $H_o$ ) of no rank correlation ( $p_s = 0$ ), the rankings are independent. The standard normal random variable  $Z$  was used to test the null hypothesis for each of the data sets represented in the figures listed. Spearman’s  $r_s$  is given for each along with the significance,  $p_s$  value. All  $p_s$  values are significant, thus rejecting the null hypothesis. See Table 4 for results.

**Survey of Undergraduate Catalogs and Department Heads**

As shown in Table 4, the highest Spearman Rank Coefficient is from the response on present technologies required (Figure 7). This indicates the survey question upon which professionals and educators most agreed. The researchers questioned if this agreement translated into curricular integration of those present technologies that at a minimum one could find in college catalogs. The search results of college catalogs for courses dedicated to the top seven agreed-upon technologies are shown in Table 5. Among these, flexible manufacturing and integrated manufacturing systems did not have a dedicated course nor was sufficient evidence found within course descriptions to warrant recording them as covering those topics. CAD/ CAM was clearly covered in 88.3% of the 60 schools with an average 6.2 hours of course work integrated into the curriculum. Lean manufacturing at 15% was next highest followed by Six Sigma at 6.7%, sensory technology at 6.7% and automated material handling at only 3.3%.

The lack of dedicated courses on flexible and integrated manufacturing

Figure 6. Participant opinion response on areas of responsibility.

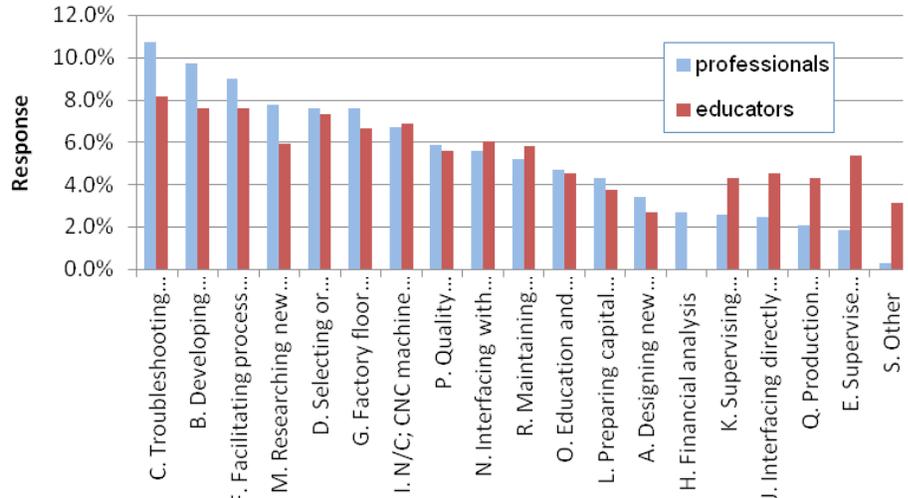
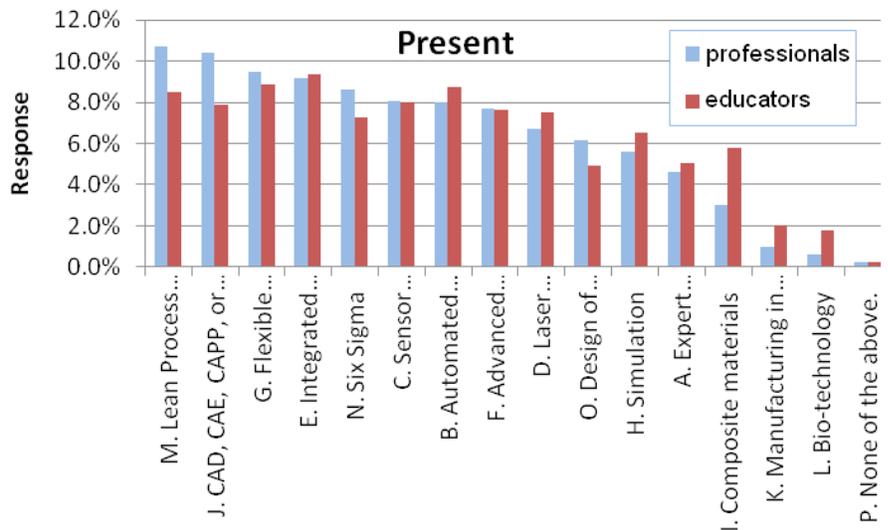


Table 3. Choices of Technologies Required

- A. Expert systems, artificial intelligence and networking
- B. Automated material handling
- C. Sensor technology, such as machine vision, adaptive control, and voice recognition
- D. Laser applications, including welding/soldering, heat-treating and inspection
- E. Integrated manufacturing systems
- F. Advanced inspection technologies: on-machine inspection, clean room, technology ...
- G. Flexible manufacturing systems
- H. Simulation
- I. Composite materials
- J. CAD, CAE, CAPP, or CAM
- K. Manufacturing in space
- L. Bio-technology
- M. Lean Process Improvement Tools
- N. Six Sigma
- O. Design of Experiments
- P. None of the above.

Figure 7. Participant opinion response on present technologies required.



systems indicates a gap between what is agreed as required technologies and what academia offers. This prompted researchers to perform a gap analysis based on course descriptions versus how department heads perceive the amount of curricular integration at these schools. Table 6 summarizes the results based on of the survey of department heads who were asked to only estimate the amount of undergraduate course hours dedicated to each topic.

Comparing the data in Tables 5 and 6 with respect to “Percent of schools with a dedicated course,” there is a factor of two or more difference for each topic (except CAD/CAM) between course catalogs and surveyed department heads. In contrast, there was only a 1.7% difference between the course catalog and the department leaders for the topic of CAD/CAM. Note a high percentage of department heads perceived courses dedicated to flexible or integrated manufacturing systems whereas none was evident in the course catalogs.

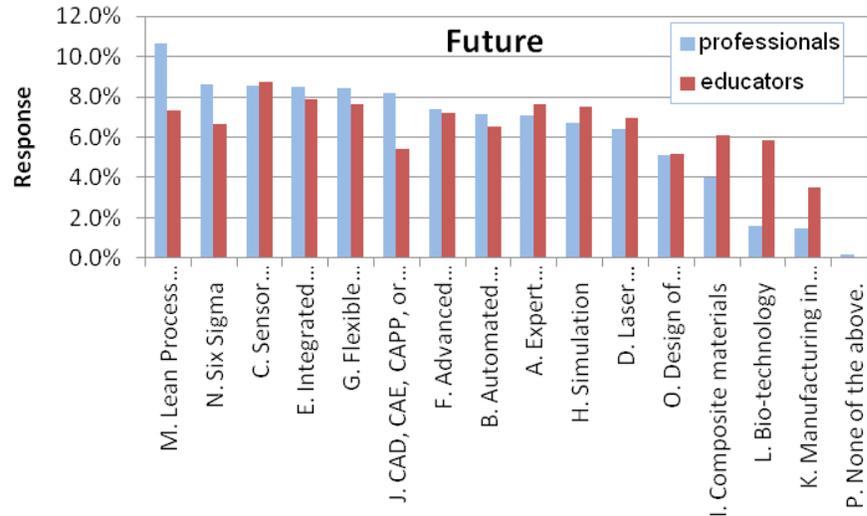
**Discussion**

A limitation of this study is that its four surveys span over several years. There is the possibility that technologies and manufacturing requirements had changed over time and so would the opinions of the participants. Therefore, it is critical that these surveys be discussed from the perspective of exploration where analysis from one survey prompted follow-up surveys.

**Evaluation of Professionals and Educators Responses**

The majority of research questions were more focused on skills rather than education levels. However, the difference of opinion evident in Figure 3 regarding minimum education indicates a fundamental difference between manufacturing professionals and educators with respect to how professionals should acquire skills. Both professional and educators strongly agree on what technologies are needed as indicated by a high correlation of  $r_s = 0.8765$  in Table 4 for Figure 7. These skills can be acquired by professionals through

**Figure 8. Participant opinion response on future technologies required.**



**Table 4. Spearman Rank Correlations and Significance**

Figure and Topic	rs	ps
Figure 4. Participant opinion response on present continuing education.	0.6876	0.0030 *
Figure 5. Participant opinion response on future continuing education.	0.7864	0.0128 *
Figure 6. Participant opinion response on areas of responsibility.	0.7596	0.0012 *
Figure 7. Participant opinion response on present technologies required.	0.8765	0.0006 *
Figure 8. Participant opinion response on future technologies required.	0.6794	0.0100 *

\* Significant if  $ps \leq .05$

**Table 5. Curricular Integration Data from ATMAE Accredited Schools' Catalogs**

Topic	Lean Mfg.	CAD/CAM	Flexible Mfg.	Integrated Mfg.	Six Sigma	Sensors Tech.	Automated Material Handling
Average hours of dedicated coursework	4.0	6.2	0	0	6.0	3.0	3.0
Percent of schools with a dedicated course	15.0%	88.3%	0.0%	0.0%	6.7%	6.7%	3.3%

**Table 6. Curricular Integration Data Estimated by ATMAE Accredited Schools' Depart. Heads**

Topic	Lean Mfg.	CAD/CAM	Flexible Mfg.	Integrated Mfg.	Six Sigma	Sensors Tech.	Automated Material Handling
Average hours of dedicated coursework	3.3	6.8	3.0	3.6	4.4	3.0	3.0
Percent of schools with a dedicated course	41.4%	89.7%	24.1%	34.5%	31.0 %	20.7%	27.6%

in-house training, conference seminars, etc. They do not have to be acquired through college courses. Even if skills are acquired through colleges, the course might be non-credit with no intention to for a degree.

Another basis for the difference of opinion on minimum education is that a much higher percentage of professional participants had two-year degrees than did the educators participants. It is reasonable that a person's level of education influences what he/she believes is an adequate education for others. However, as also shown in Figure 2, over 70% of professionals had four-year or higher degrees but their opinion response on minimum education needed was almost evenly split between two-year and four-year degrees. If they had chosen based on their educational level, then their minimum education response would have favored the four-year degree. For the educators, about 90% had four-year or higher degrees and nearly 90% of the educators chose the minimum education to be four-year degrees. This response indicates that the higher educational level of educators influenced their clear preference of four-year degrees.

The educator participants' response to the question on minimum education needed could have also been influenced by what type of school they where employed. About 87% of these participants chose a minimum of a four-year degree, which nearly matches that 85% of the participants were employed by four-year degree schools. It is reasonable that the degree in which an educator is involved is the same degree they would choose as a minimum for the professional.

Professional and educator participants also strongly agreed on present important areas of continuing education as indicated by  $r_s = 0.6876$  listed in Table 4. Stronger agreement was on future areas of continuing education. This indicates that academia may be even better positioned to address the continuing educational needs in the future for manufacturing professionals than

what is currently done. The continuing educational needs of professionals are critical to support their areas of responsibility within the workplace. There is strong agreement between professional and educator participants regarding the areas of responsibility as indicated by  $r_s = 0.7596$  listed in Table 4. This will also better position academia to support the professional.

As discussed, the highest agreement between professional and educator participants was on present technologies required. However, the least (but still strong) agreement between them was on future technologies as indicated by  $r_s = 0.6794$  listed in Table 4. This indicated a potential gap between what professionals need in the future and what academia sees it will provide regarding skills related to specific technologies. While it is an important step for academia to agree in opinion with professionals regarding technologies and continuing education, it does not necessarily translate into evidence of curricular integration.

#### **Gap Analysis of Curricular Integration**

Department heads greatly overestimated, relative to course catalogs, the amount of dedicated courses for all technologies except CAD/CAM. One possible reason for their overestimate could have been what they interpreted as a "dedicated course" for each technology topic compared to the researchers' interpretation of course catalog descriptions. Similar interpretation differences were possible regarding of what each topic specifically encompassed. However, such differences in interpretation are also possible among faculty when choosing course topics or objectives in catalog descriptions. Because department heads often initiate and guide curricular changes, their preconception of what topics are already integrated might preclude the need for change. Department heads are not the only possible source for the gap in listing agreed-upon technologies in course descriptions. All faculty must share responsibility. Furthermore, the fact that these technologies are not adequately

listed in course descriptions does not confirm the absence of integration. However, from the perspective of a manufacturing professional looking for job-related courses, curricular integration would seem to be absent.

CAD/CAM was the only technology in which the percentage of department heads claiming a dedicated course was nearly equal to that percentage found in catalogs. A possible reason for this agreement is based on that almost 90% of surveyed schools have a dedicated CAD/CAM course. It seems to be an essential part of most technology curricula. Failure to clearly identify CAD/CAM in catalogs and program literature would make these schools less attractive to potential manufacturing students. This could lead to failure of a degree program. However, identification of the other agreed-upon technologies in curricula might not be as essential to most technology schools. Professionals seeking those technology courses might be able to interpret the catalog descriptions with faculty advisement to fit their needs.

#### ***Conclusions and Recommendations***

Several conclusions and recommendations are made regarding the two main research questions involving skills and their curricular integration. The researchers recognize the limitations of such interpretations considering the rapidly changing needs of manufacturing professionals. The researchers' use of course catalogs was intended to determine only if specific technology topics were offered as a dedicated course. It is possible dedicated courses existed but were not properly identified by the researchers nor by the department heads.

There was agreement between educator and professional participants relative to present and future continuing education, areas of responsibilities, and technologies needed. This would suggest that educators are current and accurate in their understanding of industry's requirements. This echoes the findings of DeRuntz and Meier (2004)

especially with respect to Lean and Six Sigma topics. However, there is limited evidence concerning the inclusion of most identified skill topics into the curricula in schools of technology. This is supported by the underrepresentation of Quality classes offered by ATMAE accredited programs relative to the content area of its certification exam (Meier & Brown, 2008). To be relevant to the manufacturing professional, academia must step up to the opportunity of offering significantly more Quality courses with high interest topics such as Lean and Six Sigma.

While CAD/CAM is well integrated and identifiable, topics such as Lean and Six Sigma are more difficult to place within curriculum. In some schools, these topics may be considered current but not necessarily permanent curricular content. Regardless of viewpoint, schools of technology are and will always be challenged to stay current in curricular design. To that end, schools of technology should continually re-evaluate and change their curriculum to meet current and future needs. The review of catalog descriptions and department head interviews indicate that perhaps students are not able to identify the courses they need because of inadequate course description. Thus, academia needs to review and revise course titles and descriptions to enhance visibility of these critical skill topics in curricula, especially Lean and Six Sigma. In addition, consideration should be given to incorporation of this content into required courses or utilization of special topic course such as "Current Trends in Technology Management," "Emerging Technologies," "Independent Study" and "Senior Projects." Researchers should continue surveys of manufacturing professionals and educators to discover new skills, management techniques, and emerging technologies and use them to encourage curricular change.

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